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The Induction of Grain Size and Colour Mutations in Rice (*Oryza sativa* L.) by Radioisotopes

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Summary. Seven mutants with changes in grain size and in pigmentation of various organs were isolated in the M_2 and M_3 generations of the Patnai variety of winter rice after treatment with ^{32}P and ^{35}S. Some of these could be useful for breeding.

The narrow grain mutant, isolated in the M_3 generation after treatment with ^{32}P, was high-yielding and had fine grains and an increased number of long panicles.

Two short grain mutants with changed husk colour were obtained in the M_2 generation after treatment with ^{32}P. One was also early maturing.

One purple apiculus and three purple husk mutants were isolated in the M_2 generation after treatment with ^{35}S. Some of these also had reduced plant height and short grains. The purple apiculus mutant bred true for stigma and apiculus colour, but segregated for leaf sheath colour. In purple husk mutants the segregation of mutant characteristics was unusual and there was manifestation of new characters.

Introduction

Radiation-induced mutations affecting shape, size and pigmentation of various organs in rice plants are known (Ramiah and Rao, 1953; I. R. C., 1959; I. R. R. I., 1963; Basu and Basu, 1967). In an earlier report Basu and Basu (l. c.) described two short grain mutants in winter rice induced by ^{32}P. This paper presents an analysis of three mutants manifesting change in grain size and four mutants with purple pigmentation of apiculus and husk, induced by ^{32}P and ^{35}S respectively in the Patnai variety of winter rice. Some of them were useful for breeding because of their high grain-yield and fine grain qualities.

Material and Methods

Dry seeds of Patnai, a variety of winter rice (*Oryza sativa* L.), were treated with ^{32}P and ^{35}S at dosages ranging from 0.04 — 20.00 μc per seed, and 0.22 — 20.00 μc per seed, respectively. The control, treated and mutant plants were grown in replicated plots. The mutant characteristics and agronomic traits were compared with those of the mother line in some subsequent generations after isolation.

Results

a) Narrow grain mutant: One narrow grain mutant (Fig. 1) was isolated in the M_3 generation after treatment with 4 μc ^{32}P per seed. The grains of the control were long and bold; the mutant showed significant reduction in length, breadth and thickness of grains when fifty grains each from the mutant and control were measured, with the maximum reduction being observed in breadth (Table 1). The length/breadth ratio of the grains in the mutant was 5.40 compared with 4.62 in the control.

The mutant bred true for grain size character but, compared with the M_3 generation, the reduction in grain size was more pronounced in the M_4 where the length/breadth ratio was 5.75 in the mutant and 4.80 in the control (Table 1).

This mutant had higher grain-yield, more panicles and greater panicle length than the control (Table 2). However, because of reduced grain size, the 1000-grain weight of the mutant (22.87 gms.) was lower than that of the control (32.87 gms.).

b) Short grain mutants: In the M_2 generation, two plants, S. G. 1 and S. G. 2, were selected from the

Table 1. *Grain dimension (mm)* ± *S. E. in M_3 and M_4 generations*

Type	Length				Breadth				Thickness			
Generation	M_3		M_4		M_3		M_4		M_3		M_4	
Narrow grain mutant	10.54***	±0.062	10.24***	±0.076	1.95***	±0.019	1.78***	±0.015	1.63***	±0.017	1.52***	±0.013
Control	10.87	±0.074	10.85	±0.059	2.35	±0.017	2.35	±0.017	1.75	±0.019	1.85	±0.016

*** = $P < 0.001$

Table 2. *Character values ± S. E. in M_4 generation*

Type	Plant height (cm)	No. of panicles	Panicle length (cm)	Grain yield (gm/plant)
Narrow grain mutant	179.6±0.98	8.9*** ± 0.23	27.2** ± 0.14	13.11*** ± 0.72
Control	178.6±1.05	6.8 ± 0.18	26.7 ± 0.10	7.16 ± 0.57

** = $P < 0.01$ *** = $P < 0.001$

Table 3. *Grain dimension (mm) ± S. E.* in M_2 *and* M_3 *generations*

Type	Length		Breadth		Thickness	
Generation	M_2	M_3	M_2	M_3	M_2	M_3
S. G. 1	10.02 ±0.096	10.30 ±0.084	2.38 ±0.013	2.37±0.013	1.82 ±0.012	1.79 ±0.014
S. G. 2	9.02 ±0.070	9.93 ±0.072	2.29 ±0.017	2.33±0.022	1.72 ±0.017	1.71 ±0.015
Control	10.91 ±0.063	10.98 ±0.091	2.39 ±0.013	2.37±0.015	1.77 ±0.013	1.79 ±0.015
Comparisons:						
S.G.1. vs Control	0.89***±0.115	0.68***±0.124	0.01 ±0.018	0.00±0.020	0.05** ±0.018	0.00 ±0.020
S. G. 2 vs Control	1.89***±0.094	1.05***±0.116	0.10***±0.021	0.04±0.027	0.05* ±0.021	0.08***±0.021
S. G. 1 vs S. G. 2	1.00***±0.119	0.37***±0.111	0.09***±0.021	0.04±0.026	0.10***±0.021	0.08***±0.020

* = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

population treated with 0.4 μc ^{32}P per seed; they had shorter grains than the control (Fig. 2) and yellowish brown coloured husks. Compared with the control, S. G. 1 showed significant reductions in the length and thickness of grains, while S. G. 2 showed reductions in length, breadth and thickness. S. G. 2 showed a more pronounced reduction in grain size than did S. G. 1 (Table 3).

Both S. G. 1 and S. G. 2 bred true for grain size and husk colour in the M_3 and M_4 generations. These mutants were tested for yielding capacity and other agronomic characters in a progeny row trial with nine replications in the M_4 generation. Both the mutants had lower grain and straw yields than the control (Table 4).

For 1000-grain weight, the control had a significantly ($P < 0.001$) higher value (31.8 gms.) than S. G. 1 (23.7 gms.) and S. G. 2 (23.1 gms.); between the two mutants it did not vary conspicuously, the critical difference at 0.1% level being 1.01.

S. G. 1 was an early maturing type when judged by mean flowering time. The difference in mean flowering time between S. G. 1 and the control or S. G. 2

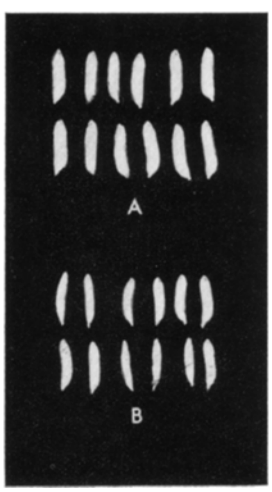

Fig. 1
Grain size: (A) control and (B) narrow grain mutant

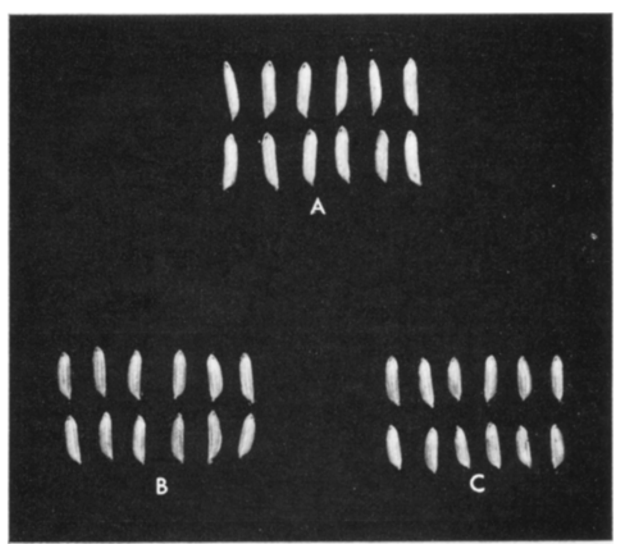

Fig. 2
Grain size: (A) control, (B) S. G. 1 and (C) S. G. 2

Table 4. *Character values* $\pm$ *S. E. in* M_4 *generation*

Type	Plant height (cm)	No. of panicles	Panicle length (cm)	Grain yield (gm/30 plants)	Straw yield (gm/30 plants)
S. G. 1	254	8.4	26.0	462	652
S. G. 2	256	8.5	25.6	520	847
Control	257	8.8	25.9	568	910
S. E.	1.8	0.26	0.26	32.1	57.3
C. D. at 5% level	—	—	—	—	171.8

was highly significant, as shown below:

Type	Mean flowering time (days) $\pm$ S. E.
S. G. 1	105.8* $\pm$ 0.10
S. G. 2	108.7 $\pm$ 0.09
Control	108.7 $\pm$ 0.09
No. of plants examined	234—270

* = $P < 0.001$

c) Purple mutants: One purple apiculus, P. A. (Fig. 3), and three purple husk mutants, P. H. 1, P. H. 2 and P. H. 3, were isolated in the M_2 generation. P. H. 1 was isolated after treatment with 12 μc ^{35}S per seed and the rest resulted from treatment with 16 μc ^{35}S per seed. The relative plant height and the pigmentation in various organs of the mutants and control were as follows:

Type	Plant height	Colour of		
		Leaf sheath	Stigma	Apiculus
P. A.	Tall	Purple	Purple	Purple
P. H. 1	Short	Green	White	Purple
P. H. 2	Short	Green	White	Purple
P. H. 3	Short	Green	Purple	Purple
Control	Tall	Green	White	Straw

The segregation pattern of the mutant characteristics and manifestation of new characters in the purple mutants in the M_3 generation were as follows:

P. A.: The mutant bred true for apiculus and stigma colour but segregated for leaf sheath colour into 199 purple:51 green. In the cross using purple leaf sheath as the pollen parent and the control with green leaf sheath as the female parent, the F_1s were all purple and in F_2 the two families segregated into 182 purple:54 green and 188 purple:57 green respectively. These results are close to a 3:1 ratio. In the M_3 generation, 17 plants had grains with awns while the control and the rest of the M_3 generation plants were awnless. In the M_2 also the grains were awnless.

P. H. 1: In the M_3 generation, the husk colour was purple in all the 148 mutant plants examined but the pigmentation was less intense in 3 plants which appeared light purple. Out of 148 plants, 145 were short and had green leaf sheath, white stigma and small grains; the 3 light purple ones were tall and had purple leaf sheath, purple stigma and large grains.

P. H. 2: Of the 281 plants examined, 269 were short with green leaf sheath, white stigma, purple husk, purple apiculus and small grains. The remaining 12 were tall and had purple stigma, light purple husk, light purple apiculus and large grains; three of these 12 plants had purple leaf sheath.

P. H. 3: Of 171 plants examined, 156 were short and had white stigma, green leaf sheath, purple husk,

Fig. 3. Portion of inflorescence of P. A. mutant with purple stigma and purple apiculus

Table 5. *Grain dimension (mm)* $\pm$ *S. E. in* M_3 *generation*

Type	Length	Breadth	Thickness
P. A.	9.86*** $\pm$0.092	2.30 $\pm$0.021	1.66*** $\pm$0.019
P. H. 1	8.86*** $\pm$0.049	2.24 $\pm$0.019	1.60*** $\pm$0.014
P. H. 2	8.75*** $\pm$0.081	2.13*** $\pm$0.026	1.57*** $\pm$0.011
P. H. 3	8.58*** $\pm$0.048	1.86*** $\pm$0.008	1.52*** $\pm$0.014
Control	10.85 $\pm$0.059	2.26 $\pm$0.015	1.85 $\pm$0.016

*** = $P < 0.001$

Table 6. *Character values ± S. E. in M_3 generation*

Type	Plant height (cm)	No. of panicles	Panicle length (cm)	Grain yield (gm/plant)	Straw Yield (gm/plant)
P. A.	163.9** ±2.53	9.2*** ±0.46	27.1* ±0.48	22.75 ±1.21	36.04 ±1.07
P. H. 1	138.8*** ±2.34	11.2*** ±0.61	22.3 ±0.37	12.41*** ±0.56	25.69** ±0.96
P. H. 2	132.0*** ±2.63	9.5*** ±0.34	22.2 ±0.34	13.45*** ±0.57	27.07*** ±0.66
P. H. 3	131.6*** ±2.25	10.2*** ±0.52	22.7 ±0.54	8.32*** ±0.63	27.45* ±1.38
Control	153.8 ±2.09	6.6 ±0.29	24.4 ±1.07	23.70 ±1.27	33.99 ±1.73

* = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

purple apiculus and small grains, and 15 were tall and had purple leaf sheath, purple stigma, light purple husk, light purple apiculus and large grains. Again, 4 of the 156 plants had larger empty glumes than normal. The glumes were long, extending to the upper edge of the palea, in contrast with the usual empty glumes of the control (Fig. 4); some were even longer than the spikelets.

Since most purple mutants had smaller grains than the control, fifty grains each from the mutants and control, excluding the segregates which had larger grains, were selected at random and measured in the M_3 generation. Compared with the control, significant reductions in length and thickness were observed in all the mutants and in breadth in P. H. 2 and P. H. 3 only (Table 5).

The agronomic characters of the mutants were compared with those of the control. P. A. was taller than the P. H. mutants and the control, but P. H. mutants were shorter than the control. The number of panicles per plant was significantly more in all the mutants than in the control. Only in P. A. was panicle length greater than in the control. The low grain-yield of the mutants (Table 6) in spite of increased numbers of panicles, may be attributed to a reduction in 1000-grain weight (Table 7). The mutants did not differ from the control in mean flowering time (Table 8).

Table 7. *1000-grain weight (gm) in M_3 generation*

Type	1000-grain weight
P. A.	28.78
P. H. 1	22.75
P. H. 2	20.98
P. H. 3	19.15
Control	32.88
S. E.	1.68
C. D. 5% level	5.29
at 1% level	7.52

Table 8. *Flowering time (days) ± S.E. in M_3 generation*

Type	Flowering time
P. A.	106.6 ± 0.21
P. H. 1	107.2 ± 0.17
P. H. 2	106.4 ± 0.21
P. H. 3	107.1 ± 0.21
Control	107.0 ± 0.20
No. of plants examined	120

Discussion

In this investigation the narrow grain mutant was of practical interest from the point of view of breeding, for it had fine grains and was superior in grain-yield to the control. The increased yield is attributable to increases in panicle length and number of panicles. These characters and the grain size bred true. The association of change in grain size with pigmentation in various plant organs, tillering nature, panicle length and plant height has recently been reported in a rice mutant (Narahari and Bora, 1963).

The short grain mutants, S. G. 1 and S. G. 2, also manifested a change in husk colour from straw to yellowish brown. The reduction in length and thickness of grains was more pronounced than reduction in breadth. These mutants bred true for grain size and husk colour. S. G. 1 differed from S. G. 2 not only in its pronounced reduction in grain size but also in earliness of flowering.

The purple mutants, P. A., P. H. 1, P. H. 2 and P. H. 3, were of academic interest. Not only was the segregation pattern unusual but some developed new characters not known in the mother line. The majority of the segregates of the P. H. mutants had green leaf sheath, white stigma and small grains while a very small proportion had purple leaf sheath, purple stigma and large grains. Murati and Mori-

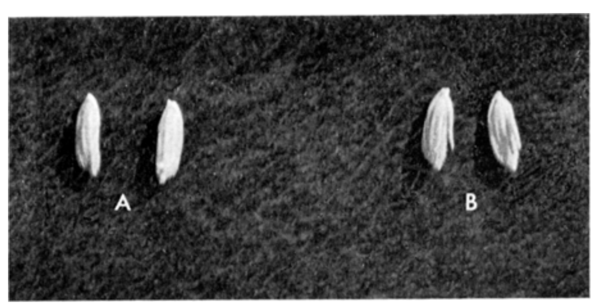

Fig. 4. Grains: (A) control and (B) P. H. 3 with enlarged outer empty glumes

waki (1955) have observed various types of character combinations and segregation of different characters in an early and purple mutant in rice induced by neutrons. Various segregation ratios are also known for the inheritance of pigmentation in leaf sheath and other organs in rice (Ramiah and Rao, 1953; Ghose *et al.*, 1960; Basu and Roychoudhury, 1965). As found in the present investigation, green is generally known to be recessive to purple in rice. However, in a cross between two wild species of *Oryza*, Richharia and Seshu (1961) have shown that green was dominant.

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